

# Acids and bases

**A**cids and **bases** are two groups of chemicals that affect you every day. In your stomach, acids help to digest your food and, in your mouth, bacteria produce acids which can destroy the enamel of your teeth. Most cleaning agents, including soap, are bases that can dissolve oil and grease from surfaces. In industry, acids are used to produce a wide range of products including drugs, explosives, fertilisers and plastics.

The products shown in the photographs below are examples of acids and bases that can be found around the home.

## Sour and bitter

Many of the foods you eat contain acids. Tomatoes, citrus fruits, vinegar and lemonade are all acidic. Acids have a sour taste; in fact, the name acid comes from the Latin word *acidus* meaning 'sour'. Some acids, like the acid found in car batteries (sulfuric acid), are very **corrosive**. They react with solid substances, 'eating' them away.

Bases have a bitter taste and feel slippery or soapy to touch. Some bases are very corrosive, especially caustic soda (sodium hydroxide). Caustic soda will break down fat, hair and vegetable matter and is the main ingredient in drain cleaners. Other bases are used in soap, shampoo, toothpaste, dishwashing liquid and cloudy ammonia as cleaning agents. Bases that can be dissolved in water are called **alkalis**. Some common acids and bases are listed in the tables below.

Acid–base **indicators** are substances that can be used to tell whether a substance is an acid or a base. Some common indicators are listed in the table on the next page. Acid–base indicators react with acids and bases and produce different colours in each. Some of them are natural dyes, while others are artificially made.

### Common acids and bases

Acid	Uses
hydrochloric acid	<ul style="list-style-type: none"> <li>to clean the surface of iron during its manufacture</li> <li>food processing</li> <li>the manufacture of other chemicals</li> <li>oil recovery</li> </ul>
nitric acid	<ul style="list-style-type: none"> <li>the manufacture of fertilisers, dyes, drugs and explosives</li> </ul>
sulfuric acid	<ul style="list-style-type: none"> <li>the manufacture of fertilisers, plastics, paints, drugs, detergents and paper</li> <li>petroleum refining and metallurgy</li> </ul>
citric acid	<ul style="list-style-type: none"> <li>present in citrus fruits such as oranges and lemons</li> <li>used in the food industry and the manufacture of some pharmaceuticals</li> </ul>
carbonic acid	<ul style="list-style-type: none"> <li>formed when carbon dioxide gas dissolves in water: present in fizzy drinks</li> </ul>
acetic acid	<ul style="list-style-type: none"> <li>found in vinegar</li> <li>the production of other chemicals, including aspirin</li> </ul>

Base	Uses
sodium hydroxide (caustic soda)	<ul style="list-style-type: none"> <li>the manufacture of soap</li> <li>as a cleaning agent</li> </ul>
ammonia	<ul style="list-style-type: none"> <li>the manufacture of fertilisers and in cleaning agents</li> </ul>
sodium bicarbonate	<ul style="list-style-type: none"> <li>to make cakes rise when they cook</li> </ul>



Some common acids and bases are found around the home.

## Indicators and their colours in acids and bases

Indicator	Colour in acid	Colour in base
methyl orange	orange	yellow
litmus (made from lichens)	red	blue
bromothymol blue	yellow	bluish-purple
phenolphthalein	colourless	pink
red wine	red	green
red cabbage juice	red	yellow

## sciFacts

Cochineal is a red dye made from the dried and ground-up bodies of female scale insects (*Dactylopius coccus*). These insects live on cactus plants in Mexico. Cochineal is used as a food colouring but is also an acid–base indicator.



An unusual indicator — *Dactylopius coccus*

## experiment

### > MAKING AN ACID–BASE INDICATOR

#### You will need:

safety glasses  
Bunsen burner, heatproof mat and matches  
tripod and gauze mat  
2 test tubes and test-tube rack  
250 mL beaker  
small jar with lid  
measuring cylinder  
glass stirring rod  
chopped red cabbage  
water  
0.1M hydrochloric acid  
0.1M sodium hydroxide (caustic soda)  
dropping pipette

- Two-thirds fill the beaker with chopped red cabbage.
- Add 50 mL water to the beaker.
- Boil the mixture for 5 minutes, gently stirring from time to time.
- Allow the mixture to cool, then pour off the liquid into the jar.

This purple solution is a natural acid–base indicator. To demonstrate this, carry out the following test.

**CAUTION: Take care not to spill any acid or base on your skin or clothes. If you do, wash the area with lots of tap water and tell your teacher immediately.**

- Add hydrochloric acid to one test tube to a depth of 1 cm.
- Add a few drops of your indicator and note the colour.
- Add the base sodium hydroxide to the other test tube to a depth of 1 cm.
- Add a few drops of your indicator and note the colour.

1. What colour is your indicator in the acid?
2. What colour is your indicator in the base?

## activities

### REMEMBER

- 1 List at least three uses of acids and three uses of bases.
- 2 How are acids and bases different from each other?
- 3 What do some acids and bases have in common?
- 4 What is the difference between a base and an alkali?
- 5 Which acid or base is used:
  - (a) to make cakes rise?
  - (b) in fizzy drinks?
  - (c) in drain cleaners?
  - (d) in vinegar?
  - (e) in cleaning agents?
  - (f) in car batteries?
- 6 What is an acid–base indicator?
- 7 What should you do immediately if you accidentally spill some acid on your arm in the laboratory?

### CREATE

- 8 Design a hazard warning label for:
  - (a) a bottle of concentrated hydrochloric acid
  - (b) a car battery
  - (c) a bottle of drain cleaner which contains mainly caustic soda.

### INVESTIGATE

- 9 Test (a) a vinegar solution and (b) a sodium bicarbonate (baking soda) solution with a range of indicators. Construct a table to show the colours of the indicators in the acid and the base. The following indicators should be fairly easy to find or make:

beetroot juice; red wine; cold tea; liquid obtained by boiling red geraniums, purple violets or blue hydrangeas; cochineal; and some laboratory indicators supplied by your teacher.

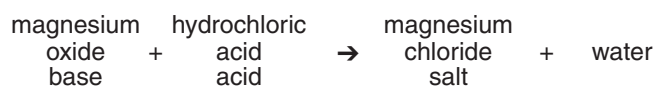
You may need to add several drops of some of the natural indicators to observe the colour change.

# When your stomach rumbles

Have you ever had indigestion? Do you burp? Does your stomach rumble? These things happen as a result of the chemical reactions in your stomach.

Your stomach contains hydrochloric acid which helps food digestion. However, if it becomes too acidic you may experience a burning feeling. This is called indigestion. The treatment for indigestion is to take an **antacid** powder or tablet. An antacid contains a base which neutralises the excess acid in the stomach and relieves the pain. As in all neutral-

isation reactions, a salt and water are produced. One commonly used antacid is milk of magnesia. It consists of a solid base, magnesium oxide suspended in water. The base reacts with the hydrochloric acid in your stomach. The word equation for this chemical reaction is:



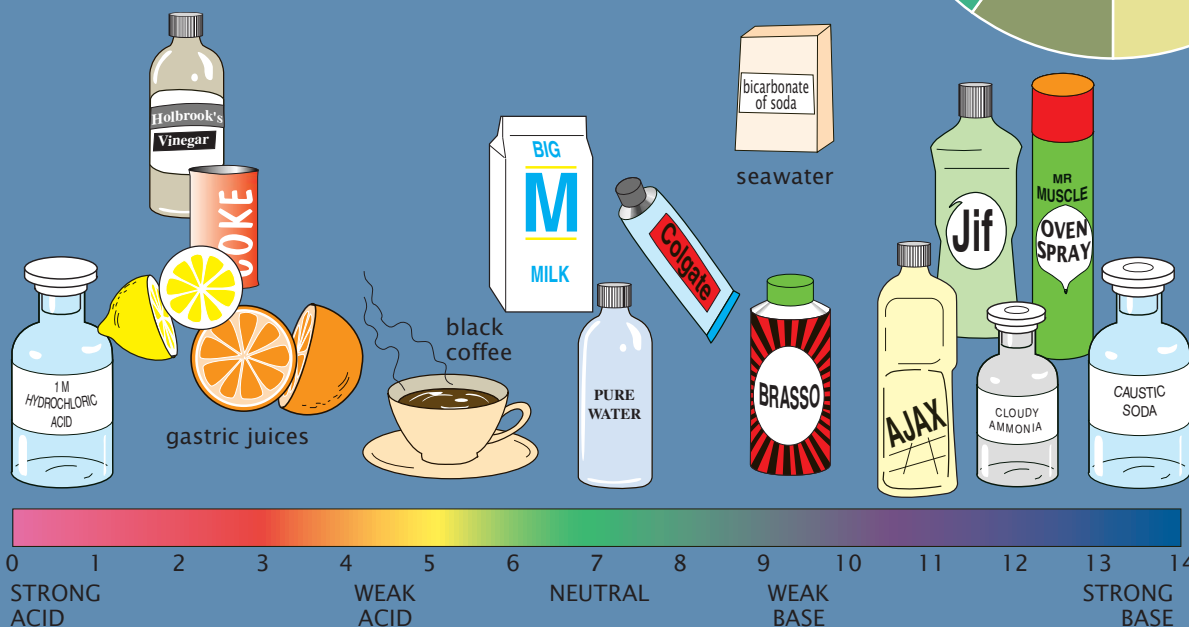
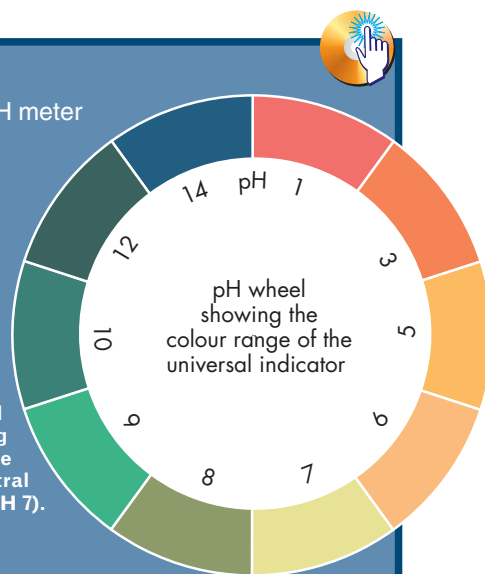
The products are the salt, magnesium chloride, and water.

## Measuring pH

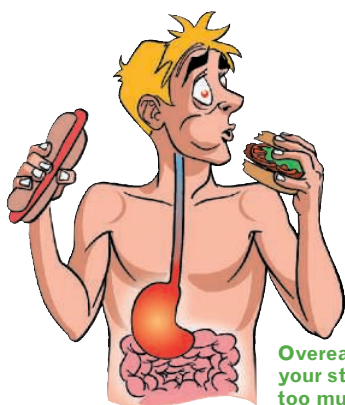
You can describe how acidic or basic a substance is by using the numbers on the **pH scale**. The pH scale ranges from 0 to 14. Low pH numbers (less than pH 7) mean that substances are acidic. High pH numbers (more than pH 7) mean that substances are basic. If a substance has a pH of 7 it is said to be neutral — neither acidic nor basic. This is shown on the pH scale below. Acids and bases can be graded from strong to weak. For example, a strong acid has a very low pH (pH 0 or 1) and a strong base has a very high pH (pH 13 or 14).

pH can be measured using a pH meter or a special indicator called universal indicator. Universal indicator is a mixture of indicators and it changes colour as the strength of an acid or base changes. The colour range of universal indicator is shown on the right.

The colour range of universal indicator. It is pink in strong acid (pH 1), blue in strong base (pH 14) and green in neutral solutions (pH 7).

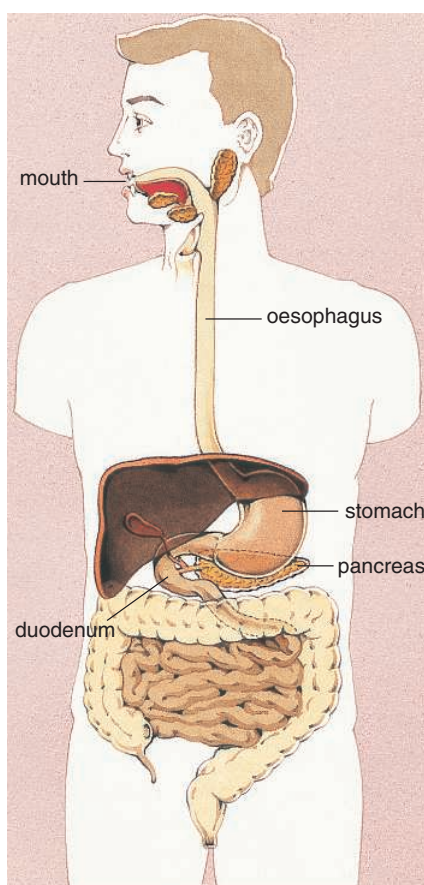


The pH values of some common substances



## sciFacts

The stomach contains very acidic liquid (pH 1.5) but the duodenum (the tube leading from the stomach) contains pancreatic juices which are very basic (pH 8.5). Pharmacologists have been able to produce tablets with a coating that protects them from attack by the stomach acid. When these tablets pass into the duodenum, the basic pancreatic juices dissolve the tablet coating, releasing the medicine into the area where it can treat the problem.



## experiment

### > ANTACIDS

#### You will need:

safety glasses  
heatproof mat  
100 mL conical flask  
0.05M hydrochloric acid solution  
universal indicator  
antacid powder (e.g. Eno salts or Mylanta)  
spatula

- Pour some hydrochloric acid into the conical flask.
- Add 2 or 3 drops of universal indicator.
- Note the colour of the solution, and determine its pH.
- The acid in the conical flask represents the stomach fluids.
- Add a spatula of antacid powder to the conical flask and gently swirl the flask.
- Observe the reaction and note the colour of the solution and the pH.

1. What happened to the pH of the solution when the antacid was added?
2. Was the level of acidity reduced by the antacid?

## activities

### REMEMBER

- 1 What causes the burning sensation in your stomach when you have indigestion?
- 2 Explain how antacids relieve indigestion.
- 3 Which type of substance has a pH value:
  - (a) less than 7?      (b) more than 7?      (c) equal to 7?

### THINK

- 4 When you take antacid tablets for an upset stomach, will the pH value in your stomach increase or decrease?

### USING DATA

A pH meter is used to measure the pH of five different substances and the results are shown in the table below.

Substance	A	B	C	D	E
pH value	6.0	12.0	3.0	7.0	8.0

- 5 Which substance could be:
  - (a) a weak base?      (c) pure water?
  - (b) vinegar?      (d) a strong base?
- 6 Which two of the substances would you expect to be the most corrosive?
- 7 Construct a bar graph to display the pH value of the five substances.

### INVESTIGATE

- 8 Find out what a peptic ulcer is, how it is caused and how it can be treated.



# Acids and bases at work

When an acid and a base are mixed, the chemical reaction that takes place is called **neutralisation**. The acid and base react to form a **salt** and water. This reaction can be described in the following word equation:



Sodium chloride (table salt) is one of many substances that are called salts. Other examples of salts are magnesium sulfate (also known as Epsom salts), copper sulfate and potassium nitrate.

## Neutralisation at home

Neutralisation reactions are used in many situations around the home. A sting from an ant or a bee is very painful as it contains an acid — formic acid. This can be neutralised by a base such as soap. A wasp sting is painful because it contains a base and can be treated by applying an acid such as vinegar. It is important to know what has bitten you so that the correct substance can be used to neutralise the sting.

Some plants grow better in acidic soils, while other plants grow best in basic soils. If a soil is too acidic, it can be neutralised with a base such as lime. The added lime can make the soil less acidic, neutral or basic, depending on how much is added. If the soil is too basic, an acid such as ammonium sulfate can be added to the soil. These neutralisation reactions in your garden can help your plants to grow by providing soil with the most suitable pH.

## Swim safely

When 'chlorine' is added to a swimming pool, it reacts with the water to produce hypochlorous acid. This acid kills bacteria and algae, keeping the pool water safe for swimming. All the chemicals in a swimming pool, when combined, need to provide a pH in the range of 7.2–7.8 for safe and comfortable swimming.

If the pH falls below 7.2, the micro-organisms will still be killed but the swimmers will get red and stinging eyes, and the

water may become corrosive and damage pool fittings. A base such as sodium carbonate (soda ash) or sodium bicarbonate (bicarbonate of soda) would have to be added to neutralise the excess acid.

If the pH rises above 7.8, the bacteria and algae will grow and the water will be unfit for swimming. To reduce the pH, an acid such as sodium hydrogen sulfate would have to be added to neutralise the excess base.

## sciFacts

The fizzy sensation that you get when you eat sherbet is due to an acid–base reaction. The sherbet consists of sodium bicarbonate and citric acid. Both of these substances are in powdered form in the sherbet and do not react with each other. When they are dissolved in the saliva of your mouth, a reaction takes place, producing carbon dioxide gas and hence the fizzing.

## Corrosive acids



Acids are corrosive. They can dissolve metals, eat away marble statues, destroy the enamel of your teeth and kill bacteria.

Because acids are corrosive, they can be very harmful. Strong acids can burn your skin and eat away clothes. If an acid is spilt on the floor, a basic powder, such as sodium bicarbonate, should be used to neutralise the acid. All spills should be reported to your teacher.

Acid can destroy the enamel on your teeth. Teeth are protected by a 2 mm thick layer of enamel made



Neutralisation reactions are important in swimming pools. Acids and bases are used to keep the pool free of harmful bacteria and algae without making your eyes sting.

of hydroxyapatite. After a meal, bacteria in the mouth break down some of the food to produce acids such as acetic acid and lactic acid. Food with a high sugar content produces the most acid. The acids produced by the bacteria can dissolve the enamel coating of the tooth. Once this protective coating is destroyed, the bacteria can get inside the tooth and cause tooth decay. The best way to prevent this chemical reaction between tooth enamel and acid from happening is to clean and floss your teeth after every meal and avoid eating sugary foods.

Since acids can be dangerous to living things they can be used as preservatives to kill bacteria. Many foods, like onions and beetroot, are preserved by storing them in vinegar (acetic acid); this is called pickling. The acid kills micro-organisms in the food, which can be kept for a long time. Before refrigeration was available, this method of food preserving was used to keep food from 'going off'.

## experiment

### > REACTION OF ACIDS WITH METALS

#### You will need:

safety glasses

bench mat

test tubes and test-tube rack

pieces of metal such as copper, iron, zinc, magnesium, aluminium

dropping bottle of 2M hydrochloric acid solution

rubber stopper

matches

When an acid reacts with a metal, a salt is formed and hydrogen gas is given off. You can test for hydrogen gas by holding a lighted match at the mouth of the test tube. If the gas is hydrogen, it will explode and make a 'pop' sound.

- Place a small piece of one of the metals in a test tube.
- Add the acid to the test tube to a depth of 1 cm.
- Observe the chemical reaction.
- Test for hydrogen gas by holding a rubber stopper over the end of the test tube for a few seconds and then placing a lighted match at the mouth of the test tube.

**CAUTION: Do not push the stopper into the test tube firmly. Just hold it in the top of the test tube for a few seconds.**

- Record your observations.
  - Repeat the test with other metals.
1. When zinc metal reacts with hydrochloric acid, zinc chloride and hydrogen gas are formed. Write a word equation for this reaction.
  2. When the lighted match produces a 'pop', the hydrogen gas is reacting with the oxygen in the air to form water. You may have noticed the water form at the top of the test tube after you performed the match test. Write a word equation for this chemical reaction.

## activities

### REMEMBER

1 Complete these word equations.

(a) acid + base →

(b) acid + metal →

2 List three examples of helpful neutralisation reactions.

3 List three examples of acids causing damage.

4 Explain why it is necessary to add 'chlorine' (which is actually calcium hypochlorite or sodium hypochlorite solution) to swimming pool water.

5 What is 'pickling' and how does it work?

### THINK

6 Complete this word equation.

acid + antacid →

7 Why do your eyes sometimes sting in a swimming pool? If they do sting, what needs to be done to the water in the pool?

8 Why do foods high in sugar cause so much tooth decay?

### CREATE

9 Create a list of safety rules for working with acids and bases. Display these as a wall chart or a PowerPoint presentation.

### INVESTIGATE

10 Find out more about acids and bases in the garden so that you can answer the following questions.

(a) Which plants prefer acids?

(b) Which plants prefer bases?

(c) Does the pH of the soil affect the colour of flowers? Give at least one example.

(d) Which substances do gardeners add to the soil to make it:

(i) more acidic?

(ii) more basic?

## Civics and citizenship: Acid rain

Every year, **acid rain** causes hundreds of millions of dollars worth of damage to buildings and statues. The photographs below show the damage that has been caused to a statue over sixty years. Forests, crops and lakes are also affected by acid rain which is blown in from industrial areas.



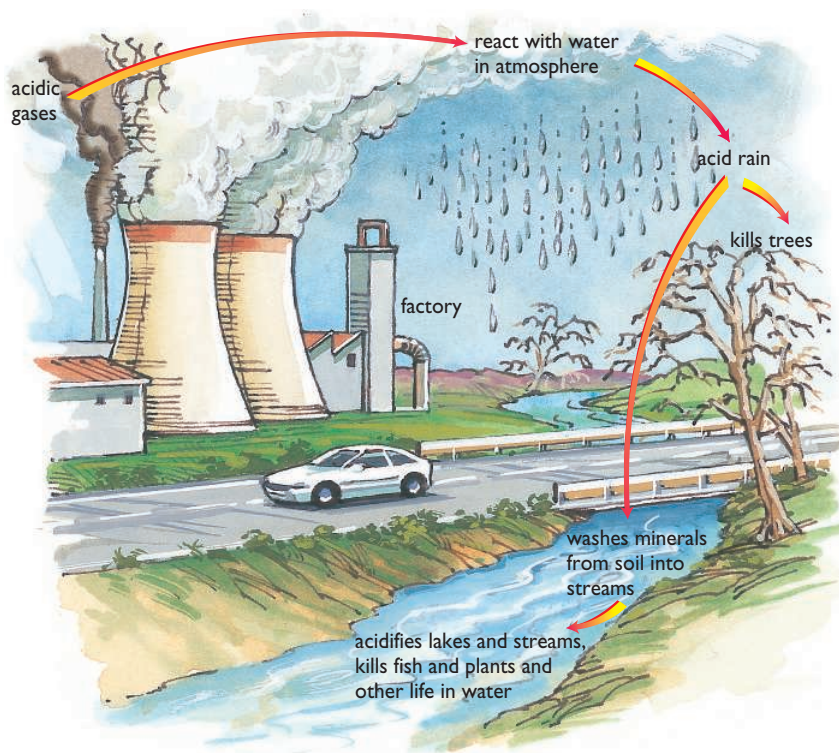
These photographs were taken in 1908 (top) and in 1969 (bottom). You can see the damaging effects of acid rain on this statue.

### What causes acid rain?

Rain is normally slightly acidic. As clouds form and rain falls, the water reacts with carbon dioxide in the atmosphere to form very weak carbonic acid. If concentrations of sulfur dioxide and nitrogen oxide are high, these gases react with the water in the atmosphere to produce sulfuric, nitric and other acids. When rain falls, it is far more acidic than it would normally be and is known as acid rain. If the acid rain falls as snow, acid snow can build up on mountains. When this snow melts, huge amounts of acid are released in a short period.

### Where do the gases come from?

Most of the gases that cause acid rain come from the burning of fossil fuels (natural gas, oil and coal) in industry, power stations, the home and cars. North America and Europe have a greater problem with acid rain because of the use of coal with a higher sulfur content than Australian coal. The sulfur dioxide released by volcanoes also contributes to acid rain.



Acid rain is formed when acidic gases (sulfur dioxide and nitrogen oxides) pollute the air and react with water.



## Damage caused by acid rain

Acid rain damages the cells on the surface of leaves and affects the flow of water through plants. It also makes plants more likely to be damaged by frosts, fungi and diseases. The acid rain collects in streams, rivers and lakes, making the waterways more acidic. A healthy lake has a pH of about 6.5 and fish, plants and insects can live in it. Acid rain causes the pH of the lake to fall. Some aquatic plants and animals cannot tolerate these acidic conditions and die. It is not only the acidic water that can kill the aquatic life. Acid rain reacts with soil, releasing minerals, which may contain elements such as aluminium. The aluminium is washed into the streams, rivers and lakes and poisons the aquatic plants and animals.

When acid rain eats into buildings and statues, it is reacting with calcium carbonate in the marble or limestone.

calcium carbonate + acid rain  $\rightarrow$  gypsum + water + carbon dioxide

The gypsum formed by acid rain on a statue is a powdery dust (calcium sulfate), which is washed away by the rain. As this chemical reaction continues, the statue is slowly eaten away.

## Solving the problem

The problem of acid rain and all the damage that it causes can be solved only by reducing the release of acidic gases into the air. Some ways of doing this include:

- looking for alternative ways of producing electricity
- encouraging people to use public transport or to car pool.

## experiment

### > INVESTIGATING ACID RAIN

Design and carry out an experiment to investigate the effect of acid rain on the growth of plants.

#### You will need:

empty milk cartons  
potting soil  
distilled water  
vinegar (or 0.1M hydrochloric acid solution)  
measuring cylinder  
seeds (e.g. lucerne, peas, cress, beans)  
universal indicator

- Cut the milk cartons so that they are about 10 cm high. These will make suitable containers for growing the seeds, 5 seeds per container.
- Test the effect of water with different pH values on the growth of the seeds. To ensure that your tests are fair, you will need to keep everything the same in your experiment, except the one thing that you are varying. In this case you are varying the level of acidity (pH) of the water that you are putting on the plants.
- Prepare a report on your investigation. This could be a written report, a video, a wall chart or an oral presentation.

## activities

### REMEMBER

- 1 What is acid rain and how is it caused?
- 2 Why is rain slightly acidic even without air pollution?
- 3 List two different ways in which acid rain can harm the plants and animals in streams and lakes.
- 4 Complete this word equation:  
acid rain + calcium carbonate  $\rightarrow$

### THINK

- 5 Motor vehicles make a large contribution to the acid rain problem. Most of them use fuel that releases acidic nitrogen oxides when it is burned. Write an account of some ways in which motor vehicle pollution could be reduced over the next thirty years.

### CREATE

- 6 Write a newspaper article about the devastation caused by acid rain.

- 7 Design a wall chart that would explain how acid rain is formed in our environment and the damage that it can cause.

### IMAGINE

- 8 Imagine that you live near a factory or power station that is producing acidic gases and causing harm to the environment. You wish to be elected onto the local government board to try to stop this problem. Write a speech that you could give at an election meeting.

### INVESTIGATE

- 9 Use the library to find out which countries are most affected by acid rain.
- 10 Find out some of the ways that damage caused by acid rain could be stopped or at least reduced.